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BROADBAND AND WIDE FIELD OF VIEW COMPOSITE TRANSDUCER ARRAY

TO ALL WHOM IT MAY CONCERN:

BE IT KNOWN THAT (1) KIM C. BENJAMIN, (2) STEPHEN E. FORSYTHE, employees of the United States Government and (3) KENNETH M. WALSH, citizens of the United States of America, and residents of (1) Portsmouth, County of Newport, State of Rhode Island, (2) Portsmouth, County of Newport, State of Rhode Island and (3) Middletown, County of Newport, State of Rhode Island have invented certain new and useful improvements entitled as set forth above of which the following is a specification:

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STATEMENT OF GOVERNMENT INTEREST

The invention described herein may be manufactured and used by or for the Government of the United States of America for Governmental purposes without the payment of any royalties thereon or therefor.

BACKGROUND OF THE INVENTION

(1) Field of the Invention

The present invention relates generally to transducer arrays, and more particularly to a composite transducer array that provides a broadband frequency response over a wide field of view.

(2) Description of the Prior Art

A variety of sonar applications such as vehicle homing require the steering of acoustic beams over a wide field-of-view. Existing homing array technology uses numerous narrowband and high-power longitudinal tonpilz resonators to form the aperture of an active transducer. Each tonpilz resonator consists of several active and inactive mechanical components that work together as a spring-mass, single degree-of-freedom system. Unfortunately, tonpilz resonators are expensive to fabricate and

offer only a limited operational bandwidth above their first length mode resonance.

To address operational bandwidth limitations of tonpilz resonators, recent work has focused on constructing multi-resonance tonpilz elements that have significantly greater bandwidth than that of the original single-mode tonpilz resonators. However, the fixed-size radiation head inherent to tonpilz resonators prevent their use in a "frequency agile" design in which array apertures can be varied in size.

SUMMARY OF THE INVENTION

Accordingly, it is an object of the present invention to provide a transducer array that can operate in a broadband frequency range over a wide field-of-view.

Another object of the present invention is to provide a broadband, wide field-of-view transducer array that is inexpensive to fabricate.

Other objects and advantages of the present invention will become more obvious hereinafter in the specification and drawings.

In accordance with the present invention, a composite transducer array has a central portion thereof formed by a piezoelectric polymer composite panel with opposing first and second surfaces. A continuous electrode is coupled to the first surface and a plurality of electrode segments electrically isolated from one another are coupled to the second surface.

Each electrode segment is shaped as an angular segment of a circular ring, while the plurality of electrode segments are arranged to define an array of concentric circular rings of electrode segments. Each electrode segment can by independently addressed so that the array's aperture can be varied in size.

BRIEF DESCRIPTION OF THE DRAWINGS

Other objects, features and advantages of the present invention will become apparent upon reference to the following description of the preferred embodiments and to the drawings, wherein corresponding reference characters indicate corresponding parts throughout the several views of the drawings and wherein:

FIG. 1 is a plan view of the segmented electrode side of an embodiment of a broadband and wide field-of-view composite transducer array in accordance with the present invention;

FIG. 2 is a side view of the composite transducer array taken along 2-2 of FIG. 1;

FIG. 3 is a side view of another embodiment in which the composite transducer array is shaped or curved; and

FIG. 4 is a cross-sectional view of an assembly housing the composite transducer array for use in an underwater environment.

DESCRIPTION OF THE PREFERRED EMBODIMENT(S)

Referring now to the drawings, simultaneous reference will be made to FIGS. 1 and 2 where a composite transducer array is shown and referenced generally by numeral 10. More specifically,

FIG. 1 is a plan view depicting the segmented electrode surface of the array and FIG. 2 is a side view depicting construction details of the array.

In FIG. 1, the segmented electrode surface of array 10 is defined by concentric circular rings of electrode segments 12. That is, each of electrode segments 12 is shaped as an angular segment (e.g., approximately 90° in the illustrated embodiment) of a circular ring of such electrode segments. Electrode segments 12 are electrically isolated from one another by means of spaces or gaps 14 therebetween. The size of spaces 14 between adjacent ones of electrode segments 12 is determined by diffraction theory as would be well understood by one of ordinary skill in the art. By way of illustrative example, four of electrode segments 12 are used to define an outermost circular ring of electrode segments. However, more or fewer electrode segments can be used in a circular ring thereof without departing from the scope of the present invention.

Each electrode segment 12 has a radial width W_R and an arc length L_A. Within a given circular ring of electrode segments, the radial width W_R and/or arc length L_A can be the same (as shown) or different for each electrode segment in the circular ring without departing from the scope of the present invention. For example, in the outermost circular ring illustrated in FIG. 1, the radial width W_R is the same for each electrode segment 12 and the arc length L_A is the same for each electrode segment 12.

Radial width and arc lengths can be increased or decreased with interior ones of the circular rings of electrode segments.

Construction of array 10 will now be explained with additional reference to FIG. 2. Electrode segments 12 are supported on a first major surface of a piezoelectric polymer composite panel 20. Details of a suitable composite panel 20 are described in U.S. Patent No. 6,255,761, the contents of which are hereby incorporated by reference. Briefly, composite panel 20 is constructed using spaced-apart piezoelectric (e.g., a ferroelectric material such as piezoceramic materials lead zirconate titanate or lead titanate) columns or rods 22 that span the thickness or height H of composite panel 20. Filling the spaces between rods 22 for the full height thereof is a viscoelastic material 24 such as a thermoplastic epoxy.

Each of electrode segments 12 can have a dedicated electrical lead coupled thereto. This can be accomplished by passing conductors (e.g., conductors 31 and 32 are illustrated in FIG. 2) through a side of composite panel 20. More specifically, conductors 31 and 32 are routed through viscoelastic material 24 and electrically coupled to one of electrode segments 12. The second major surface of composite electrode panel 20 has a continuous electrode 40 coupled thereto. Typically, the height H of panel 20 is the same throughout so that planes defined by electrode segments 12 and continuous electrode 40 are parallel to one another.

Array 10 can also be shaped to conform to simple or complex contours if viscoelastic material 24 comprises a thermoplastic material such as thermoplastic epoxy. For example, as illustrated in FIG. 3, composite panel 20 has been shaped during heating thereof such that the planes defined by electrode segments 12 and continuous electrode 40 are curved in correspondence with one another.

The composite transducer array described herein can be used as part of an underwater array assembly such as assembly 100 illustrated in FIG. 4 where like reference numerals are used to describe elements of array 10 incorporated into assembly 100. A waterproof housing (e.g., a waterproof encapsulant) 50 has array 10 fitted and sealed therein such that electrode 40 is flush with and spans an opening 52 in housing 50. That is, the plane defined by continuous electrode 40 faces out of housing 50 while the plane defined by electrode segments 12 faces into housing 50. Abutting electrode segments 12 is an acoustic absorbing material 54 such as a particle-filled epoxy. Conductors 31 and 32 pass through both composite panel 20 (as described above) and acoustic absorbing material 54 before being coupled to appropriate signal electronics 56 that can be located within and/or outside of housing 50 as illustrated.

The advantages of the present invention are numerous. Broadband operation is achieved owing to the inherent broadband resonance of piezoelectric polymer composite panel 20 used to construct the transducer array of the present invention. The

present invention also provides an improved spatial field-of-view since numerous elements may be formed by selectively applying electrodes over the array aperture to form elements having different (non-uniform) apertures. The invention teaches element apertures that can be varied in size by simply addressing electrode segments separately. High frequency responses are achieved using small sized electrode segments. The electrode segments can be combined for low frequency responses, or larger sized electrode segments could be used. The composite transducer array can be singly or doubly curved to any reasonable radii of curvature thereby providing a cost-effective means to realize truly conforming array apertures.

It will be understood that many additional changes in the details, materials, steps and arrangement of parts, which have been herein described and illustrated in order to explain the nature of the invention, may be made by those skilled in the art within the principle and scope of the invention as expressed in the appended claims.